Mass and total kinetic energy correlation in the fission of ^{204}Pb

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Introduction

The process of nuclear fission represents one of the most substantial case of nuclear transformation. In nuclear fission the nucleus splits into two fragments. The gross features of the fission process can be described within the liquid-drop model [1, 2], in which shape-dependent surface and Coulomb energy terms define the potential-energy landscape through which fission occurs. However, this macroscopic approach leads to the symmetric fragments and cannot explain observed asymmetric mass splits of actinides. Fission fragment (FF) mass distribution is an important observable to understand the fusion-fission mechanisms involved in heavy-ion induced nuclear reactions. In the present work, fusion-fission of ^{204}Pb is investigated. The survival of a non-negligible asymmetric component at finite excitation energy is discussed.

TABLE I: The excitation energies (E_x) of compound nucleus corresponding to the three beam energies, mean angular momentum for fission ($\langle l \rangle_{\rm Fiss.}$), width of measured mass distribution, width of measured TKE distribution and mean (μ) of measured TKE distribution. The mean angular momentum $\langle l \rangle_{\rm Fiss.}$ is calculated using the PACE model [3].

E_x (MeV)	$\langle l \rangle_{\rm Fiss.}$ ($\hbar$)	$\sigma_{\rm Mass\,dist.}$ (amu)	$\sigma_{\rm TKE}$ (MeV)	$\mu_{\rm TKE}$ (MeV)
49.4	14.7	12.3±0.1	11.5±0.1	142.6±0.1
42.7	9.8	11.3±0.1	10.7±0.1	142.1±0.2
37.9	5.1	10.1±0.3	···	···

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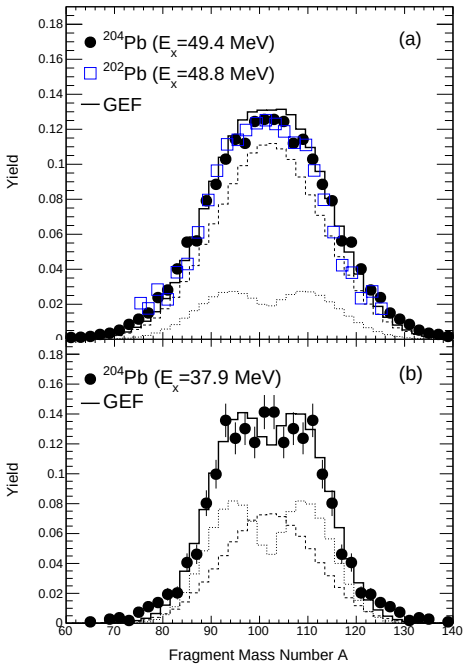

FIG. 1: Fission fragment mass distribution of ^{204}Pb in the ^{7}Li+^{197}Au reaction at E_x = 49.4 MeV (a) and at E_x = 37.9 MeV (b). The measured fission fragment mass distributions for ^{204}Pb are compared with calculations from the semi-empirical GEneral description of Fission observables (GEF) model [4]. The measured fission fragment mass distributions at E_x = 49.4 MeV is also compared with the ^{202}Pb measurement from ref. [5].

Experimental details and data analysis

A self supported target of ^{197}Au having thickness $\approx$ 280 μg/cm^2 was bombarded with a ^{7}Li beam of energy 30, 35 and 42 MeV at the BARC-TIFR Pelletron-LINAC facility. Two large area

(12.5×7.5 cm^2) multiwire proportional counters (MWPCs) were placed in a scattering chamber of diameter 1.5 m at 50° and -121.5° for the coincident detection of the fission fragments [6]. The setup gave event-by-event access to the position (x_1,y_1,x_2,y_2,) and energy loss (ΔE_1, ΔE_2) of the fragments in the detectors, as well as their time-of-flight (T_1, T_2) with respect to the beam pulse. At the lowest energy, the beam pulsing was switched off to maximize the current, and thus only the time difference $\Delta T = (T_1 - T_2)$, instead of individual time-of-flights, was recorded.

The time of flight data and position information were used to determine the fragment velocities. The emission angles, calculated from the position information, were used to obtain the linear momenta. Fragment masses were finally determined using the time-of-flight (TOF) difference method. Small corrections in the fragment mass due to their energy loss in the target were obtained on an event-by-event basis in an iterative manner for all the possible fragments. The total kinetic energies (TKE) were obtained using the deduced masses and linear momenta.

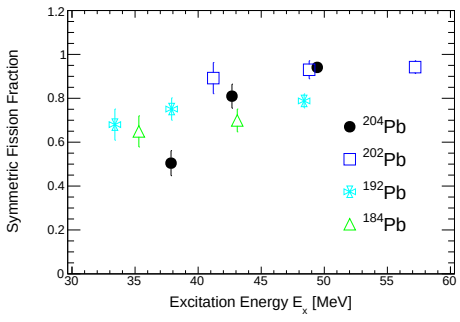

FIG. 2: The contribution of symmetric fission for ^{204}Pb in dependence on excitation energy of compound nucleus. The measured fractions for ^{204}Pb are compared and are in agreement with the data from ref. [5].

Results and discussion

Figure 1 shows the fission fragment mass distribution for ^{204}Pb at excitation energy E_x = 49.4 MeV (a) and at E_x = 37.9 MeV (b). The measured fission fragment mass distributions for ^{204}Pb are compared with calculations from the semi-empirical GEF model [4]. The symmetric and asymmetric components of fission from GEF models are shown as dashed and dotted lines along with their sum as a continuous line. The measured fission fragment mass distributions at E_x = 49.4 MeV is also compared with the data from ref. [5]. The measured FF mass distribution is in good agreement with the GEF model and ^{202}Pb measurement from ref. [5].

Figure 2 shows the dependence of symmetric fission fraction on excitation energy of compound nucleus (E_x) for ^{204}Pb. At lowest E_x the value of symmetric fraction is found to be ≈ 50 %. The measured fractions for ^{204}Pb are compared with the symmetric fission fraction of ^{202}Pb from ref. [5].

Summary

We measured the fission fragment mass and total kinetic energy distributions of ^{204}Pb populated in the ^{7}Li+^{197}Au reaction. The Fission fragment mass distribution shows the flat top structure at the lowest excitation energy characteristic to asymmetric mass distribution. The FF mass distribution is compared with the calculations of GEF model. The symmetric fission fraction is extracted for all the excitation energies of compound nucleus. At lowest E_x the value asymmetric fission is found to be ≈ 50 %. The symmetric fission fraction is in agreement with the recently published data from ref. [5] at similar E_x.

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